Solid Modeling And Structural Analysis Of Overhanging Cabin Of Dockyard

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Abstract

The aim of the present project is to design and erect a supervisor cabin. This is for the supervising staff of dockyard. The proposed cabin is to be erected above the existing truss structure of overhanging crane. It is to be designed in such a way that the entire load of the cabin should lie on its supporting columns only; the cabin load in any position should not be shared by the existing truss.

The cabin has to accommodate at least 12 members of cabin crew along with their furniture, stationery, and sometimes their tools and equipment. It has to be designed in such a way that, it should not interfere the existing framework and restricted to the space limitations of the site.

Considering the above design and structural specifications, the concept is first idealized in 3D solid modeling using the popular CATIA solid modeling package. Then the super structure (i.e. wire frame model) is analyzed in popular finite element analysis package ANSYS. The wire frame model is meshed with 3D elastic beam elements with four sets of real constants for the four different cross sections considered. Various Structural and Load variations are considered for Structural Analysis and an optimum solution is presented with least structural constraints for a spacious and comfortable cabin space for the supervising staff.

Keywords: 3D solid modeling, finite element analysis, structural analysis, supervisor cabin

1. Introduction

Solid modeling is one of the most comprehensive methods for design. This method overcomes the drawbacks of both wireframe and surface models by providing a comprehensive and complete definition of the three dimensional object. This method recognizes the solid object as a volumetric description, and it can also operates on surface and edge definitions of an object. The mass, volume, surface, and other important engineering properties can be derived using this method.

In the present approach, Boundary representation along with generalized sweeping and constructive solid geometry is extensively used wherever they are suitable. They are combined together to get maximum benefit from each and every approach. Once solid model is created the properties such as area, volume, weight, center of gravity and moment of inertia can be quickly and precisely determined. It allows developing and evaluating alternative concepts of parts and assemblies. It can be further used as model for engineering analysis.

1.1 Design of supervisor cabin of dockyard

The maintenance department of engineering division of dockyard proposed to erect a supervisor cabin in the vicinity of shop floor such that all activities of various departments are accessible and within the reach. Since there is not enough space in the ground level, the administration decided to go for a pre-fabricated supervisor cabin in the open space available above the truss of overhanging crane. It is to be designed in such a way that the entire load of the cabin should lie on its supporting columns only; the cabin load in any position should not be shared by the existing truss.

The cabin has to accommodate at least 12 members of cabin crew along with their furniture, stationery, and sometimes their tools and equipment. It has to be designed in such a way that, it should not interfere the existing framework and restricted to the space limitations of the site.

2. Literature review

Internal details of solid models can be obtained with sectioning the model at any desired position as per author [1]. Requicha [2] listed out the properties desirable in representing rigid solids. The representation should allow a useful set of physical objects to be represented. To create a valid representation, interactive solid modeling system helps effectively according to Boyse [3]. Designing a representation with all properties and how they can be interfaced to graphics software are given by authors [4] and [5].

Boolean set operations like union, difference and intersection are used to create new ones with existing objects. This is one of the most intuitive and popular methods for combining objects. Requicha [6] used regularized Boolean set operators denoted as $\cup^*$,$\cap^*$, and $-^*$ and defined such that operations on solids always yield solids. The regularized Boolean operators have been used as a user – interface technique to build complex objects. Most of the representation schemes use these operators. Constructive solid geometry is one of them.

In constructive solid geometry, the representative scheme defines a set of 3D solid shape primitives, which are relevant to the application area. These primitives are parameterized such that, any parameter can be changed interactively. In this approach the primitives are used as building blocks to construct the desired shape. Construction of complex object takes a lot of time in this approach. Usually dozen or so primitives are provided by different modeling systems. Experts after a survey found out, only four of them i.e. plane, cylinder, cone and sphere are necessary to describe majority of parts. These are also called natural quadrics. They seem to perform better than parts with more complex shapes even when stress/weight ratios are critical. Myers [7] found out that these natural quadrics are popular in industry, because these shapes are easier and economical to form and machine than complex shapes.

Sweeping an object along a trajectory through space defines a new object called a 'sweep'. Sweeps whose generating area or volume changes in size, shape, or orientation as they are swept and that follows an arbitrary curved trajectory are called 'general sweeps'.Binford [8] called these general sweeps of 2D cross sections as 'generalized cylinders'.

In a recent application of 3D solid modeling technique, Kettil and Wiberg [9] presented the integrated use of computational methods like geometrical modeling, simulation, visualization and optimization, for structural analysis and design. The focus is on 3D solid modeling and dynamic simulation. This work reiterates that 3D solid modeling and simulation are versatile tools for design of structures

3. Solid modeling of supervisor cabin

3.1 Solid Modeling of proposed cabin in CATIA

The concept is first idealized in 3D solid modeling using the popular CATIA Package. The step by step modeling process is presented (*Fig*.1 to 4) which is self explanatory. The various views of the Cabin and inside design of the work space arrangement are presented in the following figures.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 1 Issue 8, October - 2012

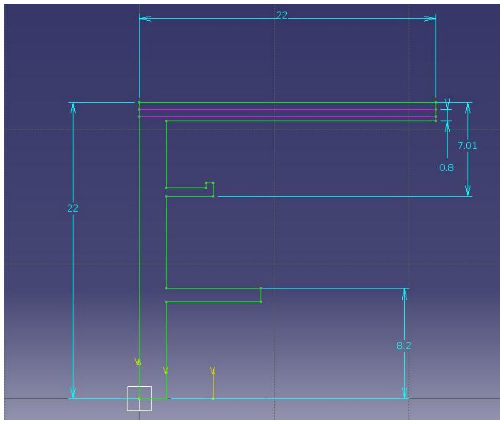


Fig.1 The sketch of the interior cross section in CATIA sketcher module

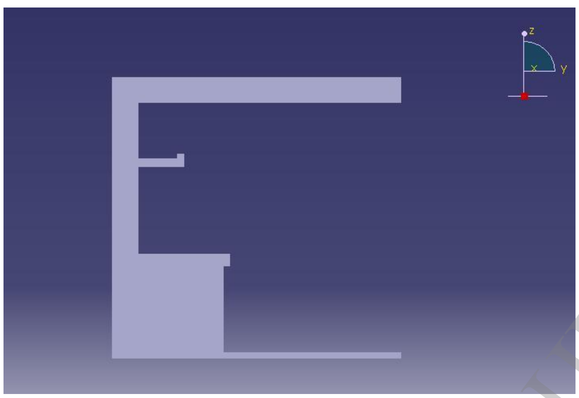


Fig.2 Side view of interiors in part design module

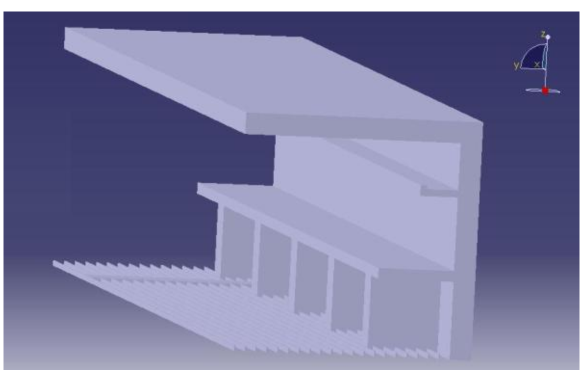


Fig.3 3D view of interiors in part design module

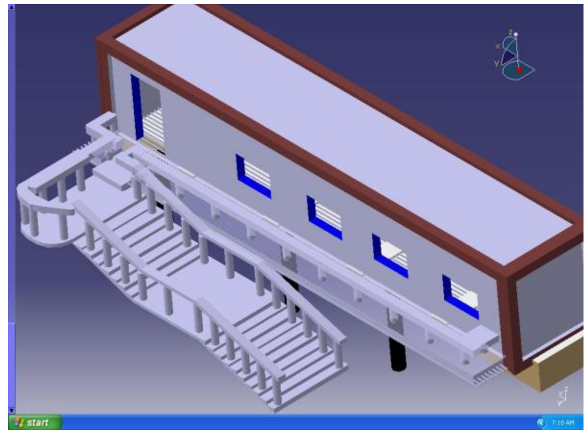


Fig.4 (a) Final adopted cabin models with staircase

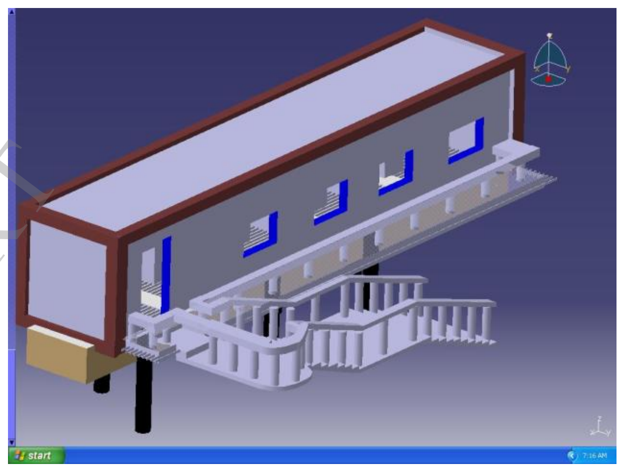


Fig.4 (b) Final adopted cabin models with staircase

4. Structural and load variations

4.1 Loads and Boundary Conditions

The columns on which the cabin stands are of ‘C’- cross section. They are to be fixed and grounded. Load (Two cases are considered for analysis, viz Case A: 4 Tons and Case B: 3 Tons) is to be applied on the bottom floor area of the cabin.

4.2 Considered Structural and Load Variations for Analysis

The following Structural and Load variations are considered for Structural Analysis

A. 3” spacing of T sections, 4 Ton, and 6 Column Supports

B. 3” spacing of T sections, 3 Ton, and 6 Column Supports

C. 3” spacing of T sections, 4 Ton, and 4 Column Supports

D. 3” spacing of T sections, 3 Ton, and 4 Column Supports

E. 4” spacing of T sections, 3 Ton, and 6 Columns Supports (Linear Arrangement of columns)

F. 4” spacing of T sections, 3 Ton, and 6 Columns Supports (Diagonal arrangement of columns)

G. 4” spacing of T sections, 3 Ton, and 4 Columns Supports

H. 4” spacing of T sections, 4 Ton, and 4 Columns Supports

4.3 The properties of the Material considered

Material considered : steel
Youngs modulus : 2.1 e 05 n/mm^2 (or) 1.95 e 10 n/ft^2
Poissons ratio : 0.3
Density : 7.86 e-6 kg/mm^3

5. Analysis of supervisor cabin

5.1 Modeling of the Cabin in Wire frame Model

Since the super structure of the cabin is made up of different forms of steel sections (like I, C, T, and L cross sections) cabin is modeled in 3D wire frame for structural analysis purpose. The 3D wireframe model of the cabin is as shown in the Fig.5

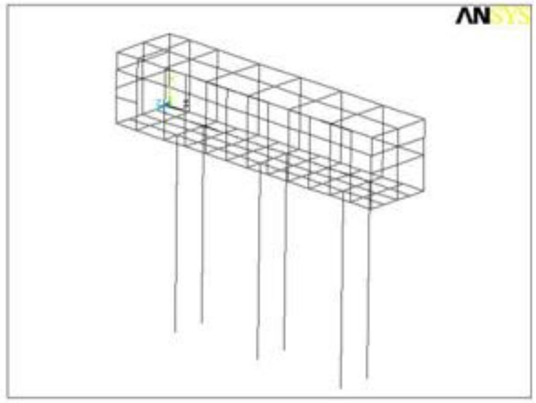
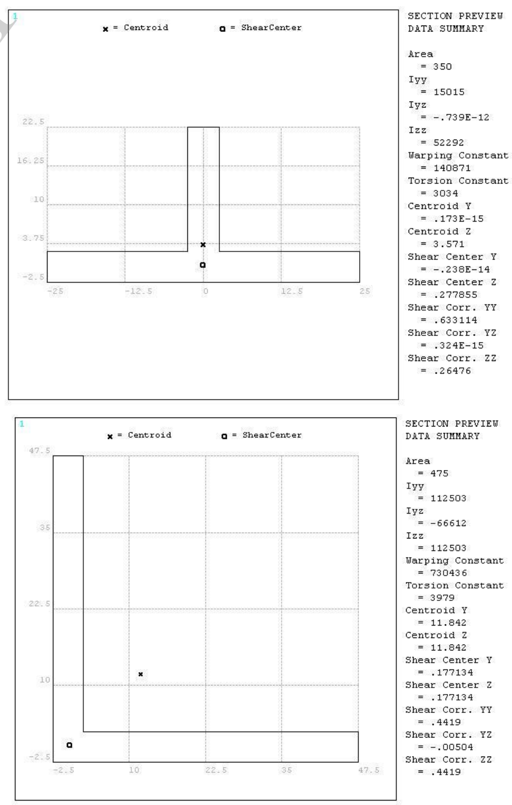


Fig.5 3D wire frame model of the cabin with pillars

5.2 Static Analysis

The wire frame model is meshed with 3D elastic beam elements with four sets of real constants for the four different cross sections considered. The cross sectional details of the sections considered are presented (*Fig*.6) as fallows.



ISSN: 2278-0181
Vol. 1 Issue 8, October - 2012

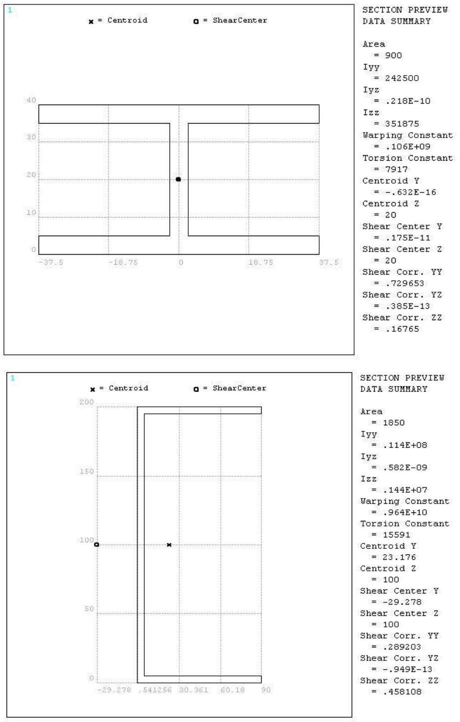


Fig.6 T, L, H and C Sections of beams considered

5.3 Loads and Boundary Conditions

The columns on which the cabin stands are of 'C'- cross section. They are fixed and grounded, so that all the six degrees of freedom (Three linear and three rotational) are constrained as shown in the figure. Load (Two cases are considered for analysis, viz Case A: 4 Tons and Case B: 3 Tons) is applied on the bottom floor area of the cabin as shown in the Fig.7.

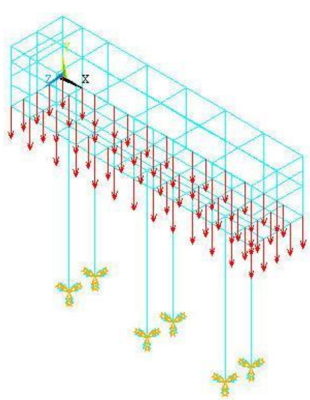


Fig.7 Loads and Boundary Conditions on wireframe model

6. Results and Discussion

6.1. Discussion on Results

The results obtained for various cases considered for structural analysis like maximum deformation and maximum stress induced are plotted in the following figures, which are under safe limits.

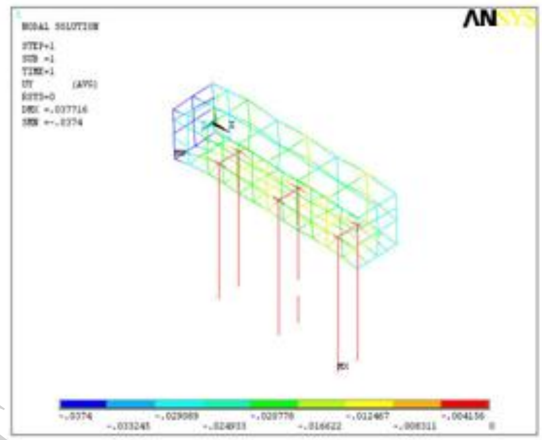


Fig.7.1 The Contour Plot of Deformation For Case B

The dark blue color indicates the maximum deformation =0.0374 ft. (OR) 11.49 mm

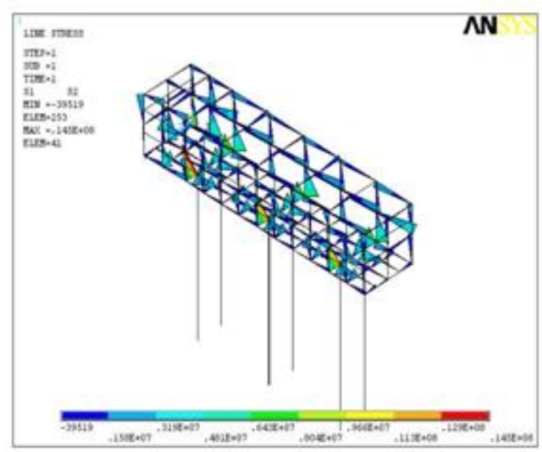


*Fig*7.2. The Contour Plot of Max. Stress Induced For Case B

The red portion indicates the maximum stress = 0.145E+08 N/ft^2 or 156.07 N/mm^2

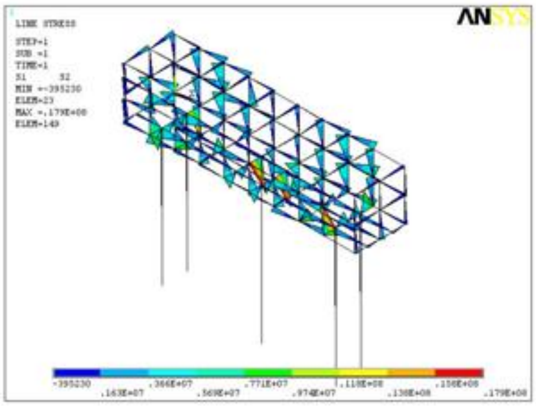


*Fig*7.6 The Contour Plot of Max. Stress Induced For Case F

The Table 7.1 presents the consolidated results for all eight cases for their maximum deformations and induced stresses in both British and SI unit systems

Table No.7.1

Case	Deflection (ft)	Deflection (mm)	Stress Induced (N/ft^2)	Stress Induced (N/mm^2)
A	0.04734	14.40	0.190e08	204.5
B	0.03771	11.49	0.145e08	156.07
C	0.0976	29.74	0.305e08	328.29
D	0.07752	23.62	0.231e08	248.6
E	0.05465	16.65	0.179e08	192.67
F	0.03676	11.20	0.171e08	184.06
G	0.07480	22.79	0.254e08	273.40
H	0.1113	33.92	0.346e08	391.80

7.2 Conclusions

From the above analysis the following are observed and can be considered for safety point of view.

1. Case F has minimum deformation and induced stresses for 4” spacing, 3 Ton Load and 6 columns arranged in diagonal fashion
2. Case B has minimum deformation and induced stresses for 3” spacing, 3 Ton Load and 6 columns
3. Case A has minimum deformation and induced stresses for 3” spacing, 4 Ton Load and 6 columns
4. From the above results it is recommended to go for either Case F or Case B

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